

## CLAIMS

What Is Claimed Is:

1. A polymeric composition having antimicrobial properties, the polymeric composition comprising:
  - a crosslinked chemical combination of (i) a polymer having side chains along a backbone forming the polymer, at least two of the side chains containing an amino group, (ii) an antimicrobial agent selected from metals, metal alloys, metal salts, metal complexes and mixtures thereof, and (iii) a crosslinking agent containing at least two functional groups capable of reacting with the amino groups.
2. The polymeric composition of claim 1 wherein:  
the polymer is a polyamide, and  
the polymer is synthesized by (i) reacting a monomer selected from unsaturated carboxylic acids, esters of unsaturated carboxylic acids, anhydrides of unsaturated carboxylic acids, and mixtures thereof, and a first amine to form an intermediate reaction product, wherein the first amine is selected from  $RR_1NH$ ,  $RNH_2$ ,  $RR_1NH_2^+$ ,  $RNH_3^+$  and mixtures thereof, wherein R and  $R_1$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, and (ii) reacting the intermediate reaction product and a second amine to form the polyamide, wherein the second amine is selected from  $R_2R_3NH$ ,  $R_2NH_2$ ,  $R_2R_3NH_2^+$ ,  $R_2NH_3^+$  and mixtures thereof, wherein  $R_2$  and  $R_3$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, wherein multiple of the R,  $R_1$ ,  $R_2$ , and  $R_3$  are in vertically aligned spaced relationship along a backbone formed by the polyamide.
3. The polymeric composition of claim 2 wherein R and  $R_1$  are alkyl.

4. The polymeric composition of claim 3 wherein the first amine is tetradecylamine.

5. The polymeric composition of claim 2 wherein the second amine is a polyalkylene polyamine.

6. The polymeric composition of claim 5 wherein the polyalkylene polyamine is pentaethylenehexamine.

7. The polymeric composition of claim 2 wherein the monomer is selected from unsaturated dicarboxylic acids, esters of unsaturated dicarboxylic acids, anhydrides of unsaturated dicarboxylic acids, and mixtures thereof.

8. The polymeric composition of claim 7 wherein the monomer is selected from maleic anhydride, maleic acid esters, and mixtures thereof.

9. The polymeric composition of claim 2 wherein the antimicrobial agent is selected from chelated silver ions, silver metal, chelated copper ions, copper metal, chelated zinc ions, zinc metal and mixtures thereof.

10. The polymeric composition of claim 1 wherein:

the polymer is a polyamide, and

the polymer is synthesized by (i) reacting an  $\alpha,\beta$ -unsaturated lactone and a first amine to form an intermediate reaction product, wherein the first amine is selected from  $RR_1NH$ ,  $RNH_2$ ,  $RR_1NH_2^+$ ,  $RNH_3^+$  and mixtures thereof, wherein R and  $R_1$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, and (ii) reacting the intermediate reaction product and a second amine to form the polyamide, wherein the second amine is selected from  $R_2R_3NH$ ,  $R_2NH_2$ ,  $R_2R_3NH_2^+$ ,  $R_2NH_3^+$  and mixtures thereof, wherein  $R_2$  and  $R_3$  can be the same or different and each

contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, wherein multiple of the R, R<sub>1</sub>, R<sub>2</sub>, and R<sub>3</sub> are in vertically aligned spaced relationship along a backbone formed by the polyamide.

11. The polymeric composition of claim 10 wherein R and R<sub>1</sub> are alkyl.
12. The polymeric composition of claim 11 wherein the first amine is tetradecylamine.
13. The polymeric composition of claim 10 wherein the second amine is a polyalkylene polyamine.
14. The polymeric composition of claim 13 wherein the polyalkylene polyamine is pentaethylenehexamine.
15. The polymeric composition of claim 10 wherein the lactone is 2(5H)-furanone.
16. The process of claim 10 wherein the antimicrobial agent is selected from chelated silver ions, silver metal, chelated copper ions, copper metal, chelated zinc ions, zinc metal and mixtures thereof.
17. The polymeric composition of claim 1 wherein the crosslinking agent is selected from the group consisting of phosphines having the general formula (A)<sub>3</sub>P, wherein A is hydroxyalkyl, and mixtures thereof.
18. The polymeric composition of claim 17 wherein the crosslinking agent is tris(hydroxymethyl)phosphine.
19. The polymeric composition of claim 1 wherein the antimicrobial

agent is selected from chelated silver ions, silver metal, chelated copper ions, copper metal, chelated zinc ions, zinc metal and mixtures thereof.

20. A polymeric composition having antimicrobial properties, the polymeric composition comprising:

(a) a first crosslinked chemical combination of (i) a first polymer having side chains along a backbone forming the first polymer, at least two of the side chains containing an amino group, (ii) a first antimicrobial agent selected from metals, metal alloys, metal salts, metal complexes and mixtures thereof, and (iii) a first crosslinking agent containing at least two functional groups capable of reacting with the amino groups; and

(b) a second crosslinked chemical combination of (i) a second polymer having side chains along a backbone forming the second polymer, at least two of the side chains containing an amino group, (ii) a second antimicrobial agent selected from metals, metal alloys, metal salts, metal complexes and mixtures thereof, and (iii) a second crosslinking agent containing at least two functional groups capable of reacting with the amino groups,

wherein the first antimicrobial agent and the second antimicrobial agent are different.

21. The polymeric composition of claim 20 wherein:

the first polymer and the second polymer are a polyamide, and

the polyamide is synthesized by (i) reacting a monomer selected from unsaturated carboxylic acids, esters of unsaturated carboxylic acids, anhydrides of unsaturated carboxylic acids, and mixtures thereof, and a first amine to form an intermediate reaction product, wherein the first amine is selected from  $RR_1NH$ ,  $RNH_2$ ,  $RR_1NH_2^+$ ,  $RNH_3^+$  and mixtures thereof, wherein R and  $R_1$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, and (ii) reacting the intermediate reaction product and a second amine to form the polyamide, wherein the second amine is selected

from  $R_2R_3NH$ ,  $R_2NH_2$ ,  $R_2R_3NH_2^+$ ,  $R_2NH_3^+$  and mixtures thereof, wherein  $R_2$  and  $R_3$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, wherein multiple of the  $R$ ,  $R_1$ ,  $R_2$ , and  $R_3$  are in vertically aligned spaced relationship along a backbone formed by the polyamide.

22. The polymeric composition of claim 21 wherein:

the first crosslinking agent and the second crosslinking agent are selected from the group consisting of phosphines having the general formula  $(A)_3P$ , wherein  $A$  is hydroxyalkyl, and mixtures thereof.

23. The polymeric composition of claim 20 wherein:

the first antimicrobial agent is selected from chelated copper ions, copper metal, and mixtures thereof, and

the second antimicrobial is selected from chelated silver ions, silver metal, and mixtures thereof.

24. The polymeric composition of claim 20 wherein:

the first antimicrobial agent is selected from chelated copper ions, copper metal, and mixtures thereof, and

the second antimicrobial is selected from chelated zinc ions, zinc metal, and mixtures thereof.

25. The polymeric composition of claim 20 wherein:

the first polymer and the second polymer are a polyamide, and

the polyamide is synthesized by (i) reacting an  $\alpha,\beta$ -unsaturated lactone and a first amine to form an intermediate reaction product, wherein the first amine is selected from  $RR_1NH$ ,  $RNH_2$ ,  $RR_1NH_2^+$ ,  $RNH_3^+$  and mixtures thereof, wherein  $R$  and  $R_1$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen,

sulfur, and phosphorus and combinations thereof, and (ii) reacting the intermediate reaction product and a second amine to form the polyamide, wherein the second amine is selected from  $R_2R_3NH$ ,  $R_2NH_2$ ,  $R_2R_3NH_2^+$ ,  $R_2NH_3^+$  and mixtures thereof, wherein  $R_2$  and  $R_3$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, wherein multiple of the  $R$ ,  $R_1$ ,  $R_2$ , and  $R_3$  are in vertically aligned spaced relationship along a backbone formed by the polyamide.

26. ~~A~~ process for rendering the surface of a substrate antimicrobial, the process comprising:

- (a) providing a polymer having side chains along a backbone forming the polymer, at least two of the side chains containing an amino group;
- (b) mixing the polymer with a crosslinking agent and a metallic antimicrobial agent selected from metals, metal alloys, metal salts, metal complexes and mixtures thereof, to produce a polymer solution, the crosslinking agent containing at least two crosslinking functional groups capable of reacting with the amino groups; and
- (c) coating at least a portion of the substrate with the polymer solution to produce a crosslinked polymer coating on the substrate.

27. The process of claim 26 wherein the crosslinking agent is selected from the group consisting of phosphines having the general formula  $(A)_3P$ , wherein  $A$  is hydroxyalkyl, and mixtures thereof.

28. The process of claim 27 wherein the crosslinking agent is tris(hydroxymethyl)phosphine.

29. The process of claim 26 wherein the substrate comprises a polymeric material selected from polyolefins, polyacrylics, polyvinyl chloride, polyamides, polyurethanes, polyurethaneureas, silicone urethane copolymers,

polyvinylpyrrolidone, polyvinyl alcohols, cellulosic materials, polystyrene, polyesters, fluorinated polymers, silicone polymers, natural rubber, polycarbonates, and mixtures thereof.

30. The process of claim 26 wherein the antimicrobial agent is selected from chelated silver ions, silver metal, chelated copper ions, copper metal, chelated zinc ions, zinc metal, and mixtures thereof.

31. The process of claim 26 wherein:

the polymer is a polyamide, and

step (a) comprises: (i) reacting a monomer selected from unsaturated carboxylic acids, esters of unsaturated carboxylic acids, anhydrides of unsaturated carboxylic acids, and mixtures thereof, and a first amine to form an intermediate reaction product, wherein the first amine is selected from  $RR_1NH$ ,  $RNH_2$ ,  $RR_1NH_2^+$ ,  $RNH_3^+$  and mixtures thereof, wherein R and  $R_1$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof; and (ii) reacting the intermediate reaction product and a second amine to form the polyamide, wherein the second amine is selected from  $R_2R_3NH$ ,  $R_2NH_2$ ,  $R_2R_3NH_2^+$ ,  $R_2NH_3^+$  and mixtures thereof, wherein  $R_2$  and  $R_3$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, wherein multiple of the R,  $R_1$ ,  $R_2$ , and  $R_3$  are in vertically aligned spaced relationship along a backbone formed by the polyamide.

32. The process of claim 31 wherein R and  $R_1$  are alkyl.

33. The process of claim 32 wherein the first amine is tetradecylamine.

34. The process of claim 31 wherein the second amine is a polyalkylene

polyamine.

35. The process of claim 34 wherein the polyalkylene polyamine is pentaethylenehexamine.

36. The process of claim 31 wherein the monomer is selected from unsaturated dicarboxylic acids, esters of unsaturated dicarboxylic acids, anhydrides of unsaturated dicarboxylic acids, and mixtures thereof.

37. The process of claim 36 wherein the monomer is selected from maleic anhydride, maleic acid esters, and mixtures thereof.

38. The process of claim 26 wherein:

the polymer is a polyamide, and

step (a) comprises: (i) reacting an  $\alpha,\beta$ -unsaturated lactone and a first amine to form an intermediate reaction product, wherein the first amine is selected from  $RR_1NH$ ,  $RNH_2$ ,  $RR_1NH_2^+$ ,  $RNH_3^+$  and mixtures thereof, wherein R and  $R_1$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof; and (ii) reacting the intermediate reaction product and a second amine to form the polyamide, wherein the second amine is selected from  $R_2R_3NH$ ,  $R_2NH_2$ ,  $R_2R_3NH_2^+$ ,  $R_2NH_3^+$  and mixtures thereof, wherein  $R_2$  and  $R_3$  can be the same or different and each contain between about 1 and 50 carbon atoms and are optionally substituted with heteroatoms oxygen, nitrogen, sulfur, and phosphorus and combinations thereof, wherein multiple of the R,  $R_1$ ,  $R_2$ , and  $R_3$  are in vertically aligned spaced relationship along a backbone formed by the polyamide.

39. The process of claim 38 wherein R and  $R_1$  are alkyl.

40. The process of claim 39 wherein the first amine is tetradecylamine.

41. The process of claim 38 wherein the second amine is a polyalkylene polyamine.

42. The process of claim 41 wherein the polyalkylene polyamine is pentaethylenehexamine.

43. The process of claim 38 wherein the lactone is 2(5H)-furanone.